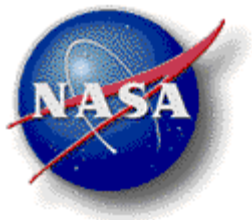# User Training Manual

SHOPBOT PRS ALPHA 96

ARC SPACESHOP

April 2013
Rev. A

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, CA

Table Of Contents

I.   Introduction

This document is for the user qualification training of the ShopBot PRS Alpha located at the Ames SpaceShop facility on the 2nd floor in Building 220. Before a user operates the machine, he/she must have signed the required documentation as described in the "SpaceShop Standard Operating Procedures". For additional information, please see a SpaceShop staff member.

II.   ShopBot PRS Alpha

The ShopBot PRS Alpha is a CNC machine that allows users to cut, drill, carve and machine wood, plastic, aluminum and other materials along 3 axes, X, Y, & Z.

The specifications of the printer are as follows:
- Table Cutting Dimensions: 69 inches x 96 inches
- Table Area: 6624 square inches = 46 square feet
- Table Thickness: ¾" Plywood Bottom Layer, ¾" MDF Top Layer

Figure 1: ShopBot

III.   Safety Precautions

a. *ShopBot Safety*

SHALL…
- You **SHALL** notify SpaceShop staff prior to running any job.
- You **SHALL** wear ear protection.
- You **SHALL** wear closed-toe shoes at all times.
- You **SHALL** wear eye protection when working with tools and processes that involve chemicals, metal shards, wood chips or sawdust.
- You **SHALL** clean up your space after every job session, and leave 10-15 minutes for cleanup prior to shop closure.
- You **SHALL** secure badge and any loose items that might get caught in moving machinery.
- You **SHALL** make small cuts at slow speed otherwise you will risk breaking the cutting tool, and ruining your material.
- You **SHALL** hold the ShopBot Dongle(contains ESTOP,RESET, START buttons) in your hand, during the entire operation of the ShopBot, for quick access to the ESTOP in case of emergency.
- You **SHALL** always be ready to react in case an operation fails.
- You **SHALL** make sure the spindle collet and cover nut are properly secured and not over-tightened.
- You **SHALL** always use a sacrificial layer under the material you are cutting, so as not to cut into the table below.
- You **SHALL** ensure the End Mill is fastened securely inside the spindle collet, before starting your operation.
- You **SHALL** ensure all tools are in good condition before use.
- You **SHALL** use your sense of sight and sound to keep yourself aware of the operational conditions of the ShopBot for safe use.

SHALL NOT…
- You **SHALL NOT** leave a machine unattended while in operation.
- You **SHALL NOT** touch materials and chips being cut since they can be hot.
- You **SHALL NOT** wear or have any loose objects on your body while operating this machine, including badges, jewelry, loose clothing, and loose long hair.
- You **SHALL NOT** work alone while in the SpaceShop.

IV.   Step-by-Step Tutorial

    a. Tools Required

- PartWorks software
- ShopBot 3 software
- ¼" End Mill
- ½" End Mill
- Collet for a ¼" End Mill
- Collet for ½" End Mill
- Cover Nut
- Drill
- 8 Screws to hold down material
- Sacrificial Layer, 8" x 8" sheet of MDF
- Dust collector
- Shop vacuum
- Wrench
- ToothHolder
- Calipers

    b. Getting Started

1. **WALK AROUND** the ShopBot to make sure there are no wires or items on the ShopBot bed **OBSTRUCTING** the machine or gantry.

2. **CHECKOUT KEY** Lock for the **SHOPBOT**.

3. Turn **ON** your computer if it's not already running.

4. Start by turning **ON** the ShopBot with the **RED START** switch on the right side of the machine near the control box, to the **ON** position (Figure 2).

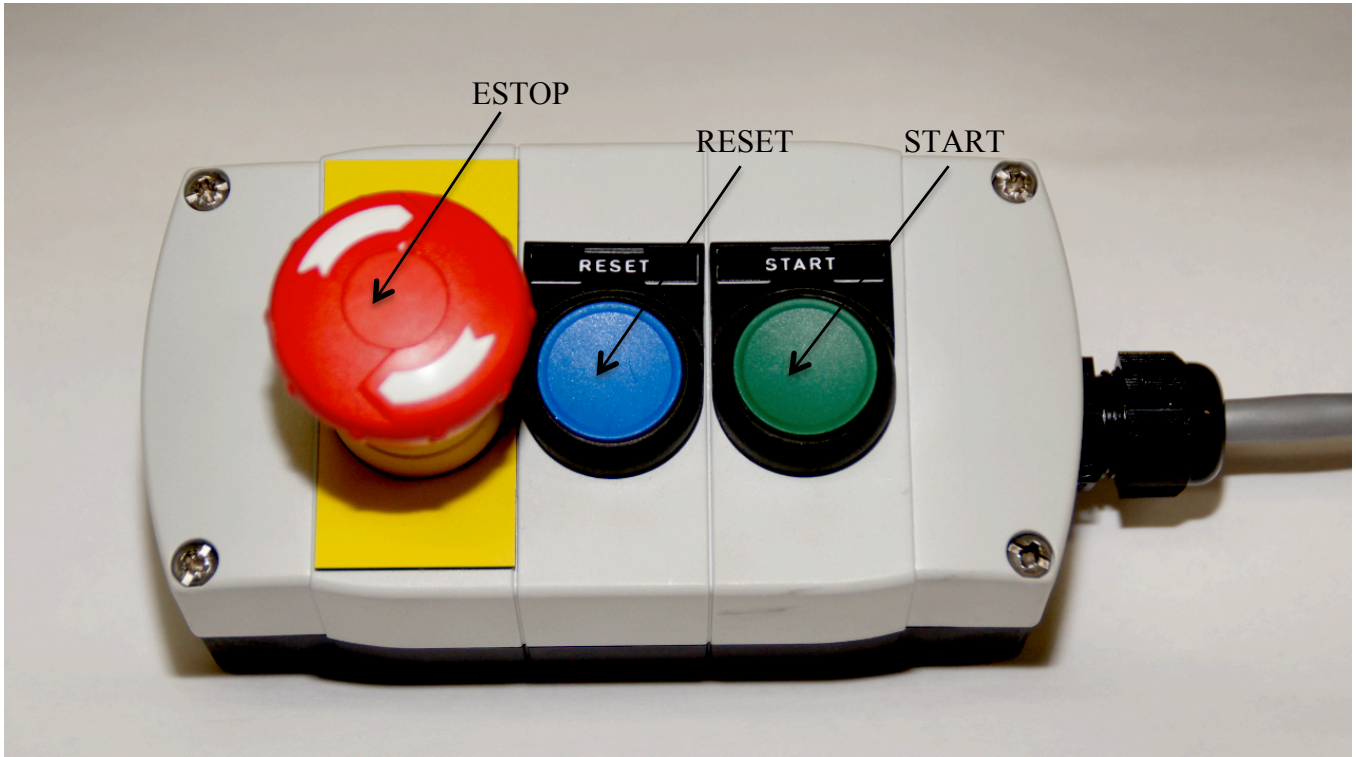**Figure 2: ShopBot Power On Switch**

Figure 3: ESTOP Switch on Dongle

5. Ensure **ESTOP** (Figure 3) switches are in the **OFF** position by rotating the **RED STOP** button on the **DONGLE COUNTER CLOCKWISE** (Figure 4).

   NOTE: If they were **ON**, then this rotation allows the button to pop out to let you know they are now **OFF**. Check the **ESTOP** (Figure 5) on the gantry, which must also be rotated and popped out.
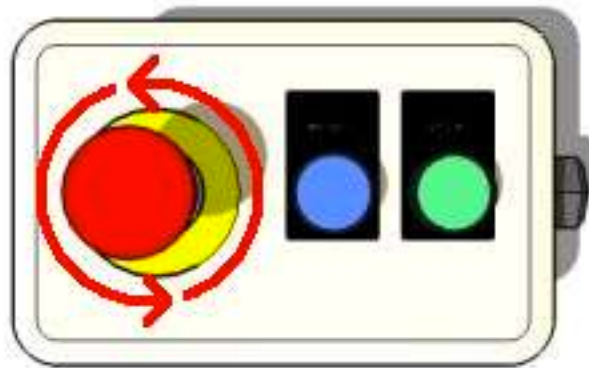

Figure 4: Rotate ESTOP to place in the OFF position

Figure 5: ESTOP Switch on gantry

6. Double click on **SHOPBOT 3** icon on your desktop, to launch the control software (Figure 6).

Figure 6: ShopBot 3 Icon

7. To manually move the spindle, type **K** on the digital keypad by pressing **K** on your **KEYBOARD** (Figure 7).
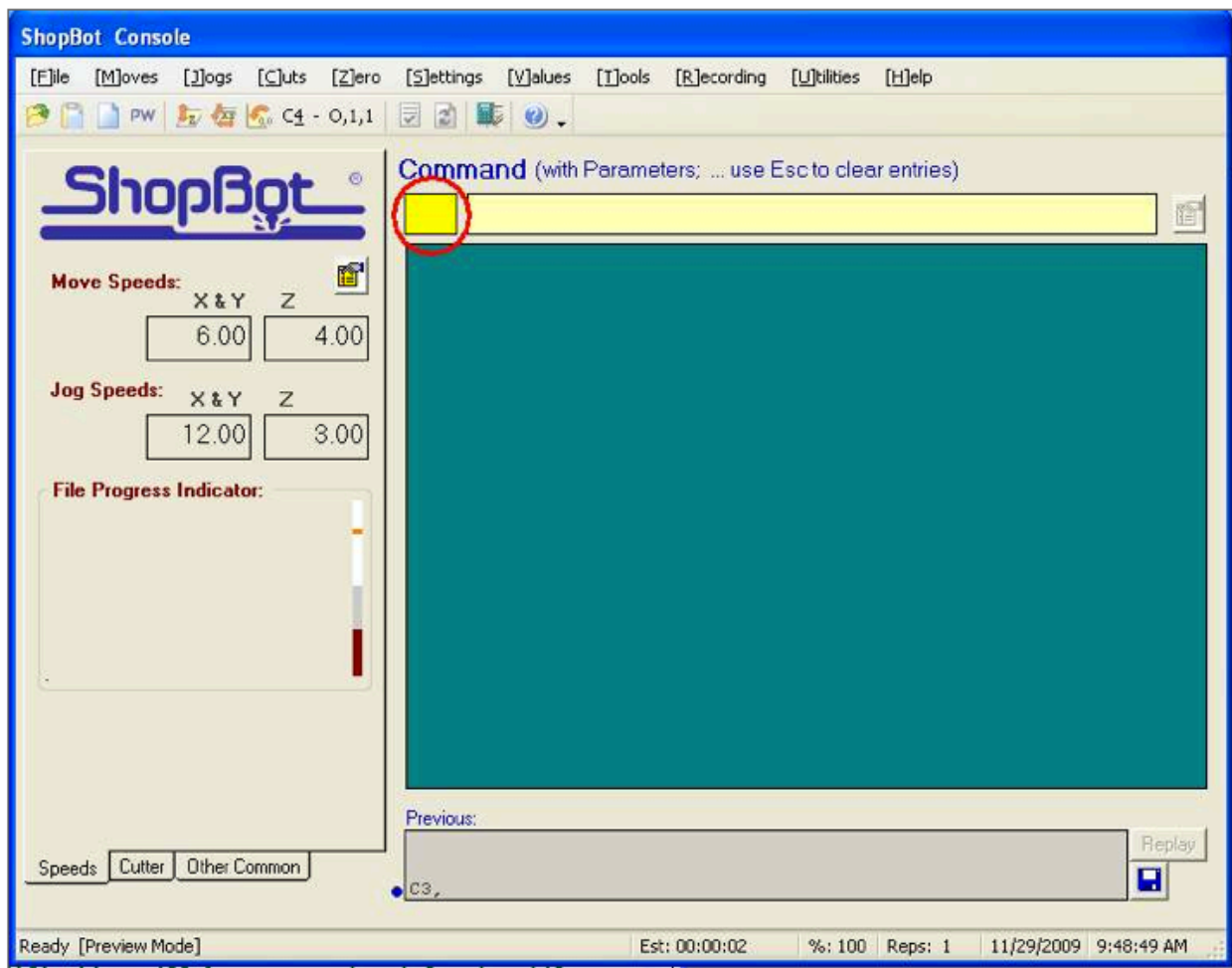

Figure 7: Command Menu in ShopBot 3 Software Interface

8. An error (Figure 8) may appear several times. Make sure to rotate and pop out both ESTOP switches.
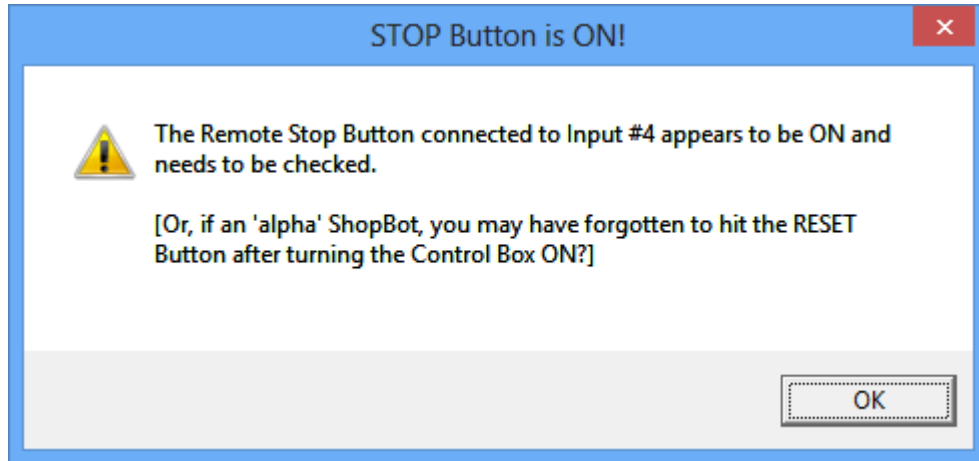

Figure 8: Command Menu in ShopBot 3 Software Interface

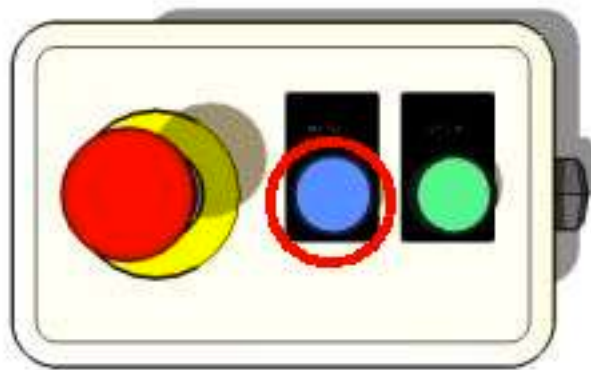9. Click on the **BLUE RESET** button on the **DONGLE** (Figure 9) (Figure 3).

Figure 9: Blue Reset Button

10. Repeat step 7. Type **K** on your keyboard to open the KeyPad Dialog Box (Figure 7).

11. Click on the **UP** and **DOWN** arrow keys on your keyboard to move the gantry along the **Y AXIS**. See the location change in the Keypad Dialog Box.

12. Click on the **LEFT** and **RIGHT** arrow keys to move the head along the **X AXIS**. See the location change in the Keypad Dialog Box.

13. Click on the **PAGEUP & PAGEDOWN** keys to move the head along the **Z AXIS**. See the location change in the Keypad Dialog Box (Figure 10).
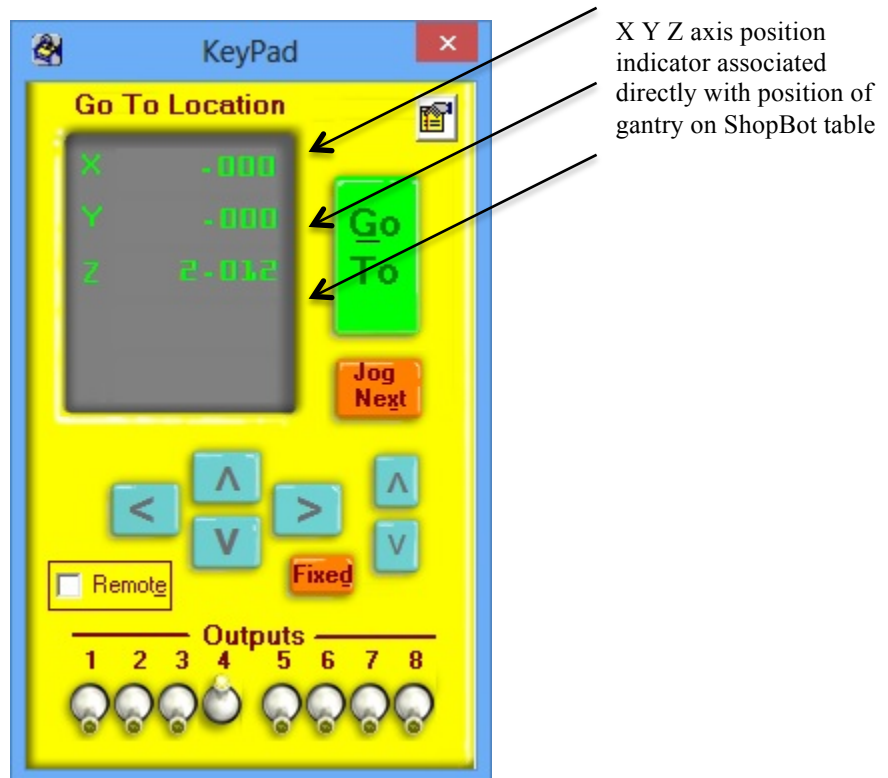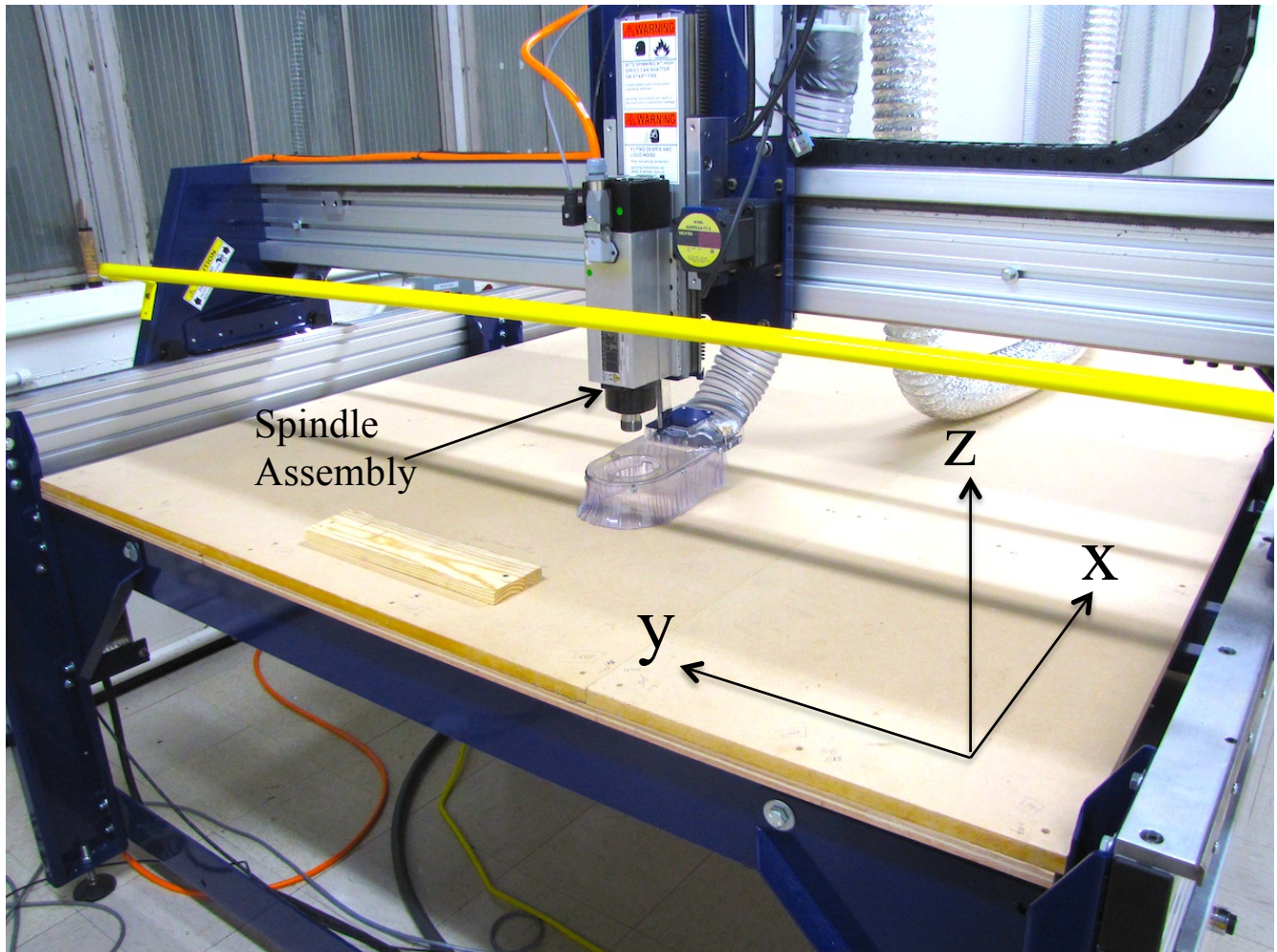

X Y Z axis position indicator associated directly with position of gantry on ShopBot table

Figure 10: KeyPad Dialog Box

Figure 11: Axes on the ShopBot Table

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14. The following are the most common short keys used in the ShopBot. Take the time to familiarize yourself with each key on the ShopBot 3 Command Line (Figure 7).

MX 1 [move X AXIS +1"]

MY 1 [move Y AXIS +1"]

MZ 1 [move Z AXIS +1"]

M2 1,1   [move in X AXIS +1", move in Y AXIS +1"]

M3 1,1,1 [move in X AXIS +1", move in Y AXIS +1" , move in Z AXIS +1"]

MH [move home]

K [keypad arrows to jog up and down, and PGDWN and PGUP for Z AXIS]

C2 [to zero in Z AXIS]

C3 [internal home command automatically zero's all three axes at 0,0,0 of the machine table]

C4 [starts the Shopbot spindle]

Z2 [sets the X AXIS & Y AXIS zero at the current position of the spindle]

Z3 [sets the X AXIS & Y AXIS & Z AXIS zero at the current position of the spindle]

15. Unscrew the **THUMB SCREW** (Figure 12) to lower **DUST SKIRT** covering over **SPINDLE**. This makes it easier to access the spindle assembly (Figure 11). See Figures 12-14 to perform this operation.
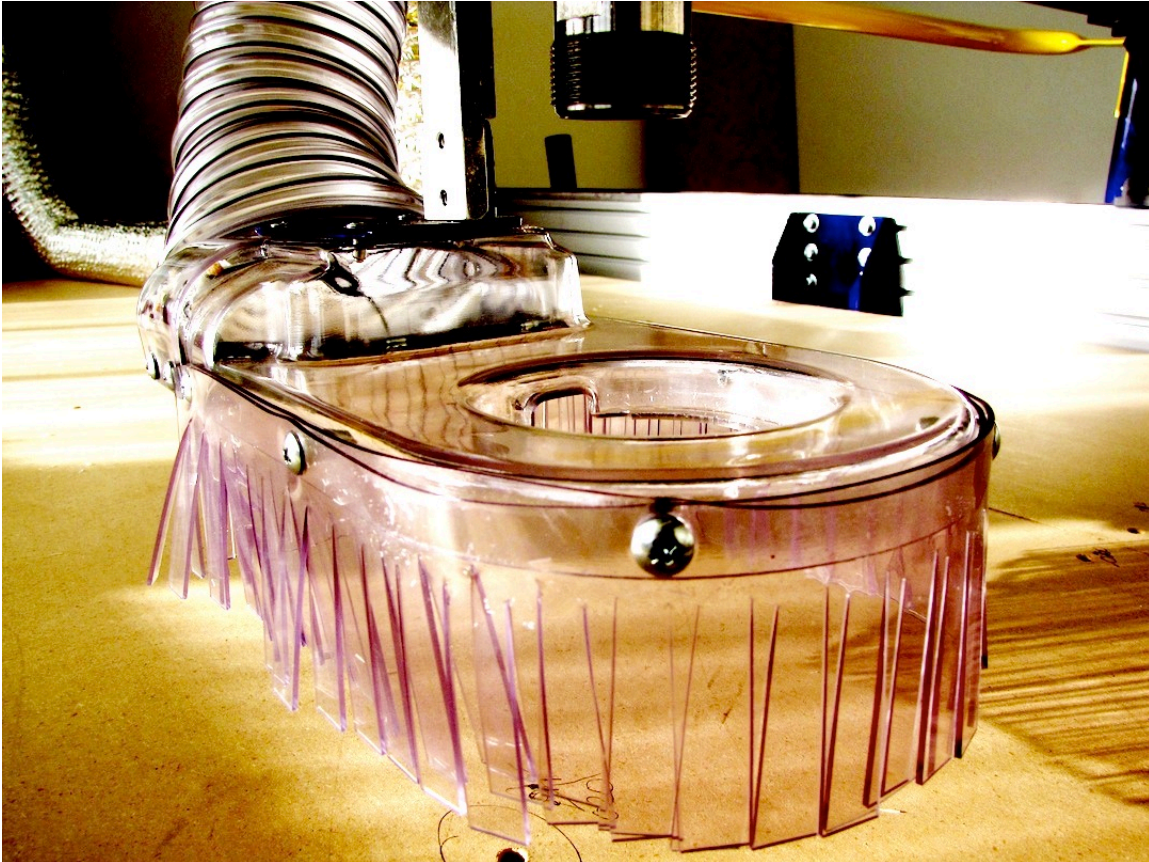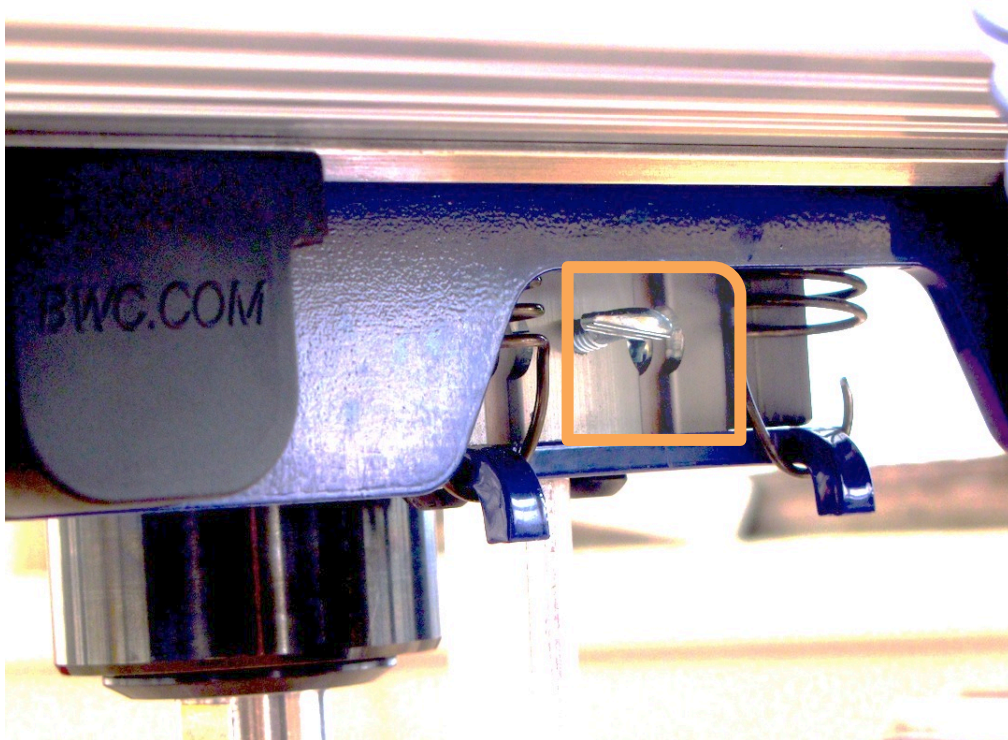

Figure 12: Dust skirt lowered

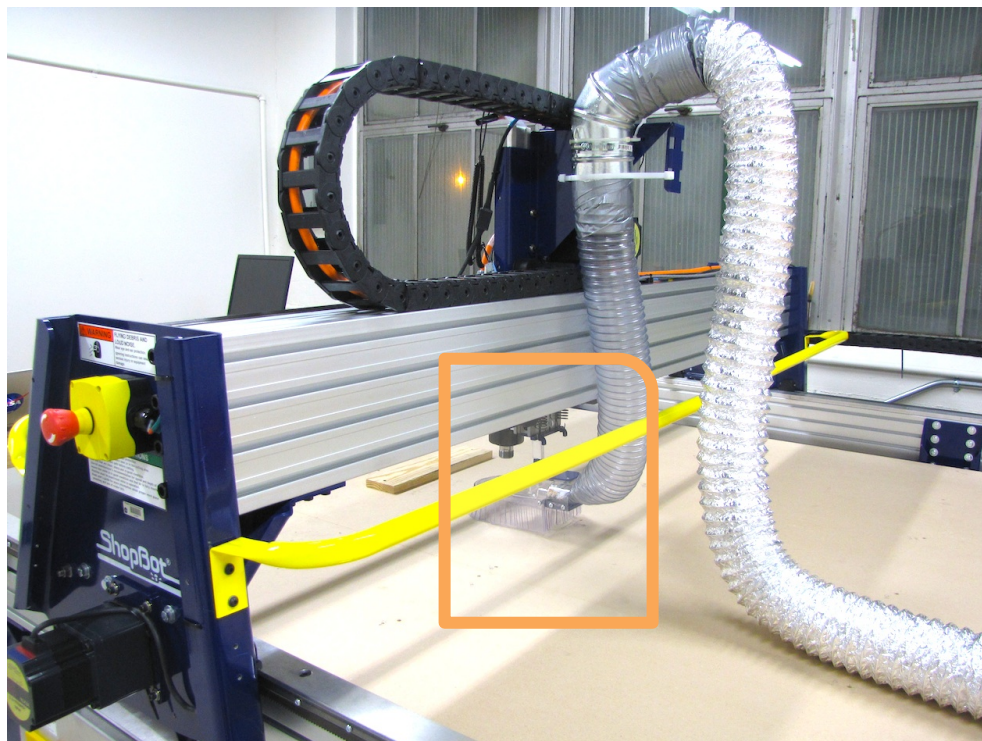**Figure 13: Thumb Screw holds the Shroud in Place**

Figure 14: Location of Thumb Screw behind Spindle Assembly

Figure 15: Spindle Assembly Components

16. Insert the desired **COLLET** into the **COVER NUT** until it clicks and you cannot physically pull one out of the other (Figure 15 &16).

    NOTE: The Collet depends on the diameter of your End Mill, therefore you need to make sure your End Mill fits tightly into the Collet before moving on. If not, choose another Collet appropriate for your End Mill size. For our tutorial, we shall use the larger End Mill to plane off about 1/8" of material to even out the top layer. Later, we will use a smaller End Mill to perform the actual cutout.
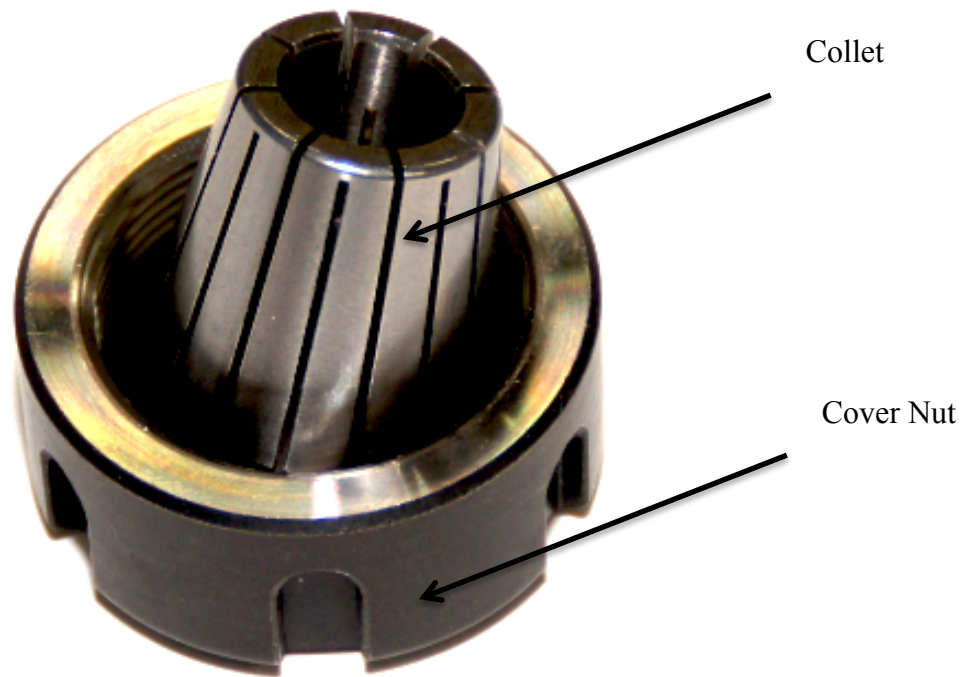
Collet

Cover Nut

Figure 16: Collet Loose in Cover Nut
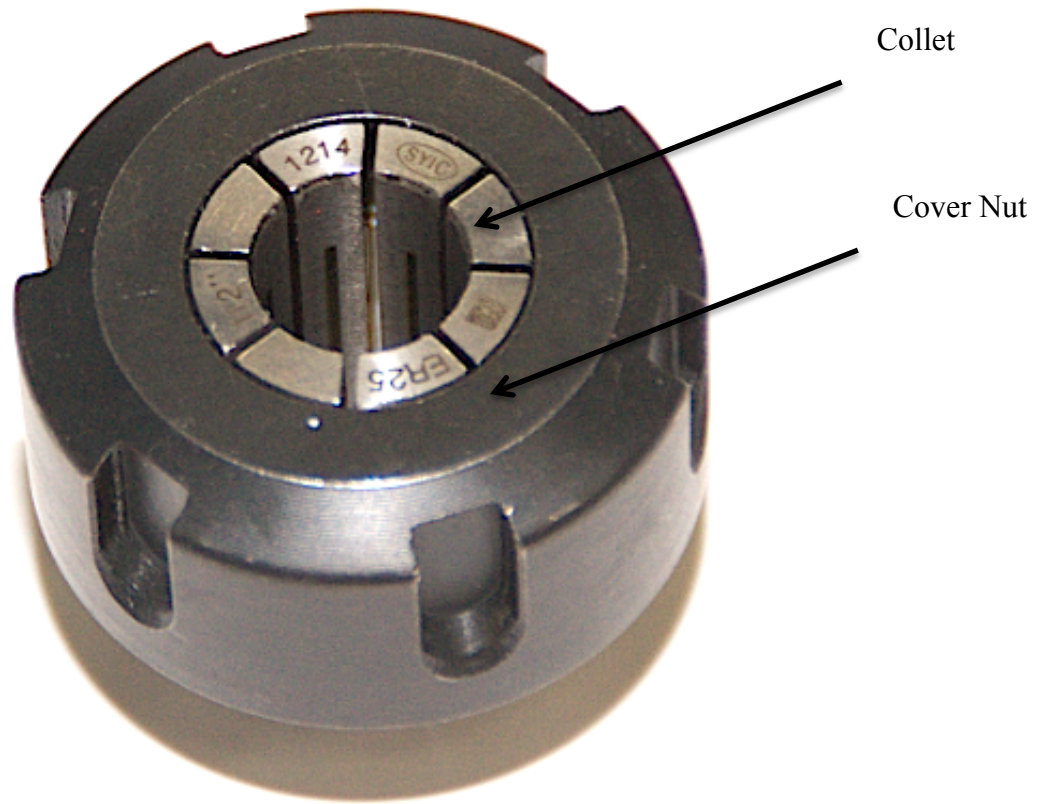
Collet

Cover Nut

Figure 17: Collet clicked into Cover Nut

17. Insert the **END MILL** into **COLLET** securely.

End Mill
Spiral Flute

End Mill
should not be
inserted into
the Collet past
this line

End Mill Shaft-
Any part of the
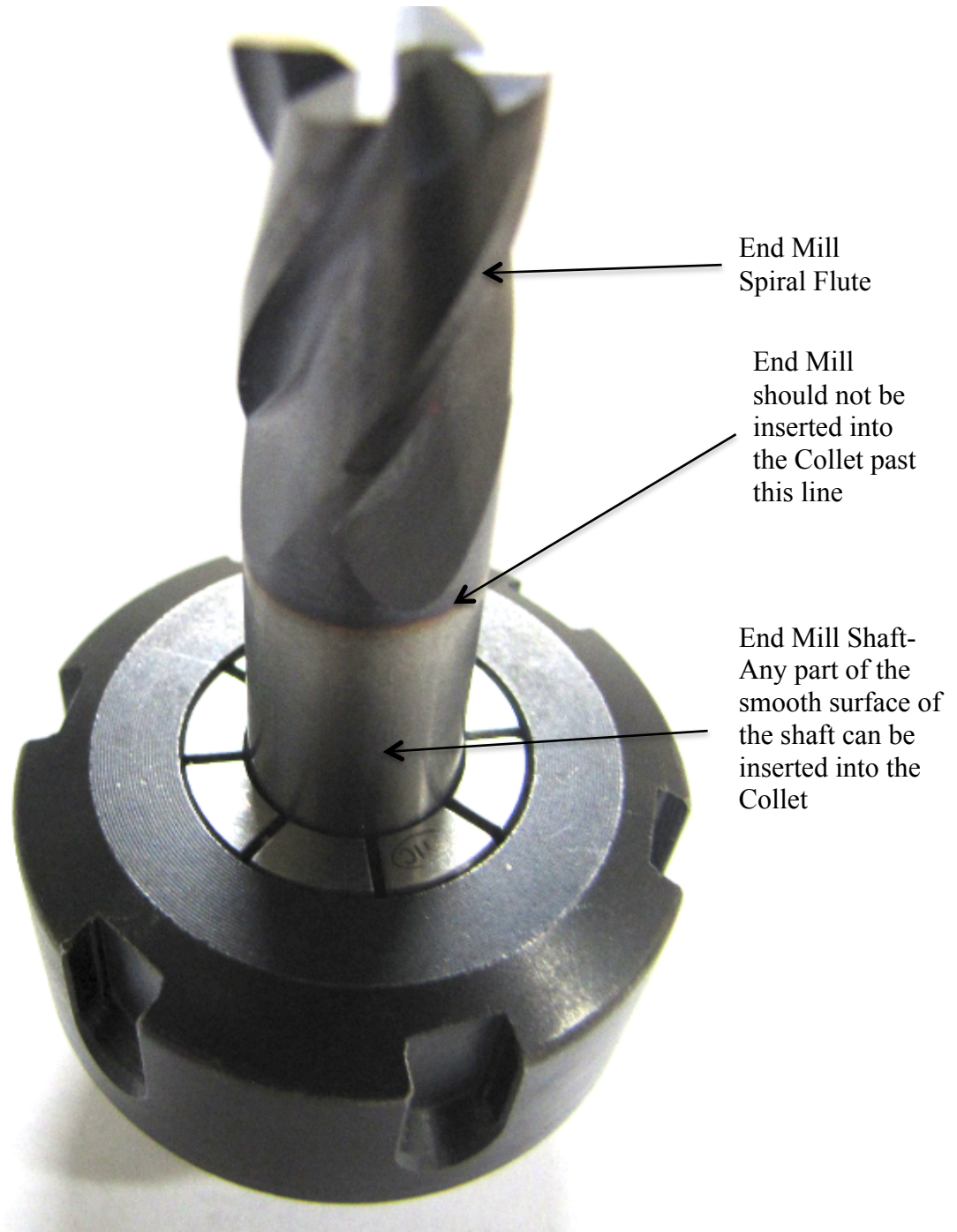smooth surface of
the shaft can be
inserted into the
Collet

Figure 18: End Mill inserted into Collet

18. Screw the **COVER NUT ASSEMBLY** from step 17 to the **SPINDLE** loosely. Turn the **COVER NUT** counter-clockwise with your right hand, and hold the threaded part steady until you cannot rotate the **COVER NUT** anymore (Figure 19).

19. Use the **TOOTHOLDER** and **WRENCH** as illustrated in Figure 19, and with both hands rotate **TOOTHOLDER** and **WRENCH** away from each other to tighten**. DO NOT OVERTIGHTEN**!

Figure 19: Spindle Assembly

20. Now you can **RAISE UP** the **DUST SKIRT** cover all the way up and lock into place (Figure 20).

NOTE: Rule of Thumb: The bottom of the dust skirt should eventually be 1/8" < top of your material thickness.
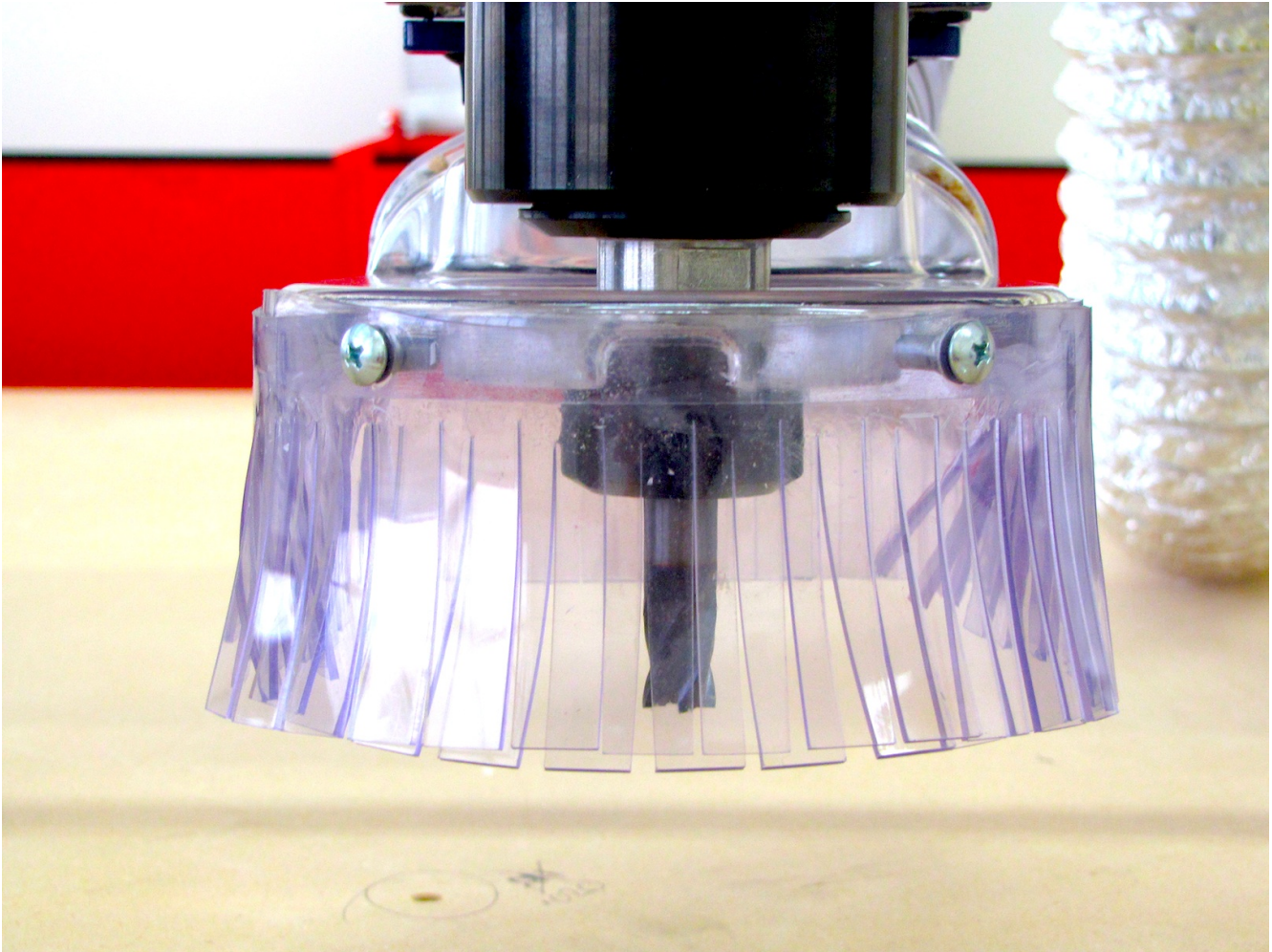

Figure 20: Dust Skirt

21. Before you can secure your material, you need to **MOVE** the **GANTRY AWAY** towards the middle of the ShopBot table, to give you space for attachment of your material. If you need to review how to move the gantry, review steps 9-12.

22. Measure the **THICKNESS** of your **CUTTING MATERIAL** with **CALIPERS** and make note of this, since you will refer to this in the PartWorks File.

23. **SECURE** the **SACRIFICIAL LAYER** to the ShopBot table by drilling 2" screws on four corners of this rectangular layer. This can be plywood or MDF.You have now secured the sacrificial layer to the ShopBot table, and have ensured that your operation cannot ruin the table.

NOTE: In Figure 21, we are not showing a sacrificial layer. Instead, we are only showing the final layer attached directly to the table layer.

24. **SECURE** the **FINAL LAYER (circular piece)** to the **SACRIFICIAL LAYER** using one of the attachment methods on the following page. For this tutorial, start by drilling two screws, one on each side of the **FINAL LAYER.** These screws should penetrate the **FINAL LAYER** & **SACRIFICIAL LAYER**(may or may not penetrate **TABLE LAYER** depending on length of screws and material height).
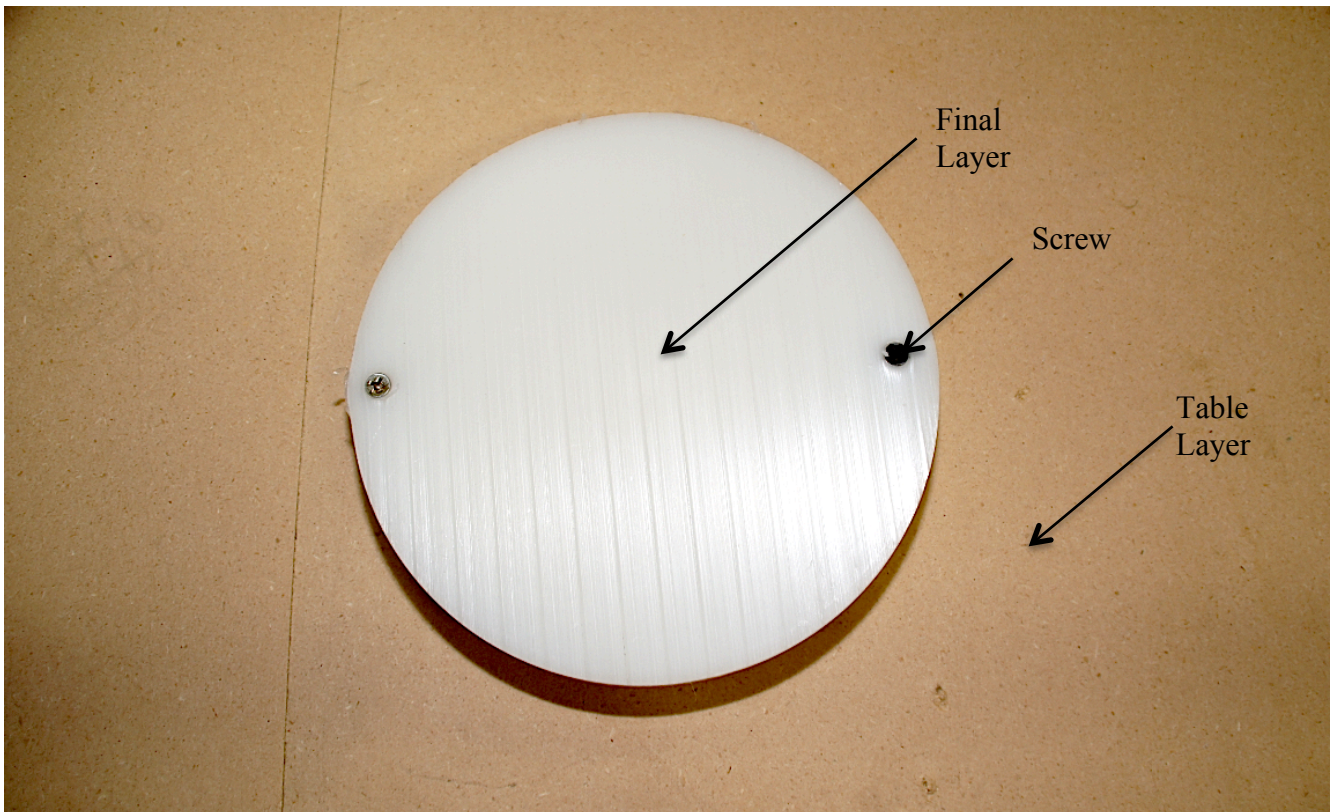

Figure 21: Material Attached to ShopBot table with Screws

Additional methods of attachment for securing material to the ShopBot table:

a) CLAMPS- In order to clamp your material to the ShopBot table, the clamps should be placed along edges whereby the gantry and spindle will not come into contact with the clamps. Clamps are used for larger materials that span the entire bed surface from one edge to the other. This is not the preferred method of securing material to the ShopBot table, unless you combine this method with one of the other two.

b) SCREWS- Screws are preferred because of their effectiveness to firmly secure material to the bed of the ShopBot. It's best to leave a few inches of extra material along two or more opposing edges to place the screws. Always make sure before starting your job, that screws will not cross paths with the End Mill during operation. The best way to make sure this does not happen is to conduct an air pass whereby the machine traces its path above the material.

c) DOUBLE SIDED TAPE- Carpenter's Tape is useful for dampening vibration and to make sure smaller cut-outs will remain in place once the entire profile of the piece is cut away. The object is not completely rigid, and therefore the object may result in less precise cuts. For best results, use tape with clamps and screws.

25. In the ShopBot 3 Editor command line, type **K** to open the Keypad dialog box and now move the **SPINDLE** o your desired position in the **X** and **Y AXIS** until the tip of the End Mill aligns with the center of your material.

    NOTE: Use a T-Square or any ruler to find the center of the circle. Mark this point with a pen. This will be your reference in positioning the End Mill as close as possible to this point.

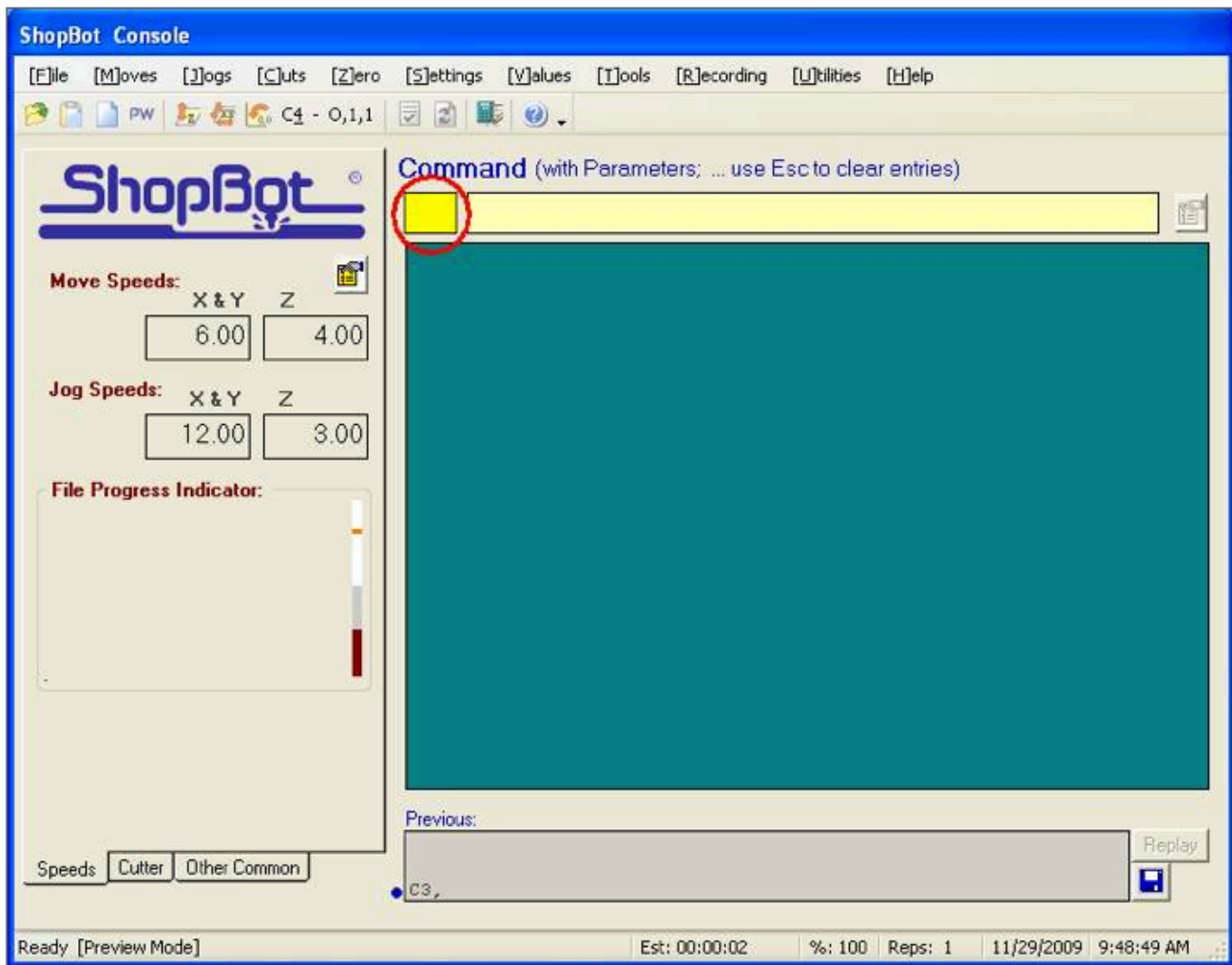26. Typing **Z2** in the command line to set this point as the official Zero point.

Figure 22: ShopBot 3 Command Line

27. To set the **Z AXIS**, move the Shopbot to the desired position by clicking on the keypad icon in the control panel interface, or by typing **K**. Move the spindle roughly to the center of your final layer where you will place your aluminum plate.

    Note: Your material will not be flat, but this is ok. For more precise operations, we would have made sure to use a material that is more uniform in thickness. Our circular pieces in this tutorial, were cut as cross-sections from an extruded cylinder, hence variations in thickness.

28. Once you have your **SPINDLE** at some position, take the aluminum plate out of the side pocket next to the **SPINDLE** assembly. Place this plate on the **FINAL LAYER**, **DIRECTLY** underneath the **ENDMILL** (Figure 23).

29. Establish a good electrical ground between the **COPPER PLYER** and a metal surface preferably on the frame of the ShopBot, such that both **PLYER** and **METAL** surface make contact (Figure 23).

    NOTE: This contact is your Ground connection, eliminating static electricity that may interfere with sensing and movement of the plate and mill, and to help prevent erroneous errors such as stop switch hits or lost position errors.
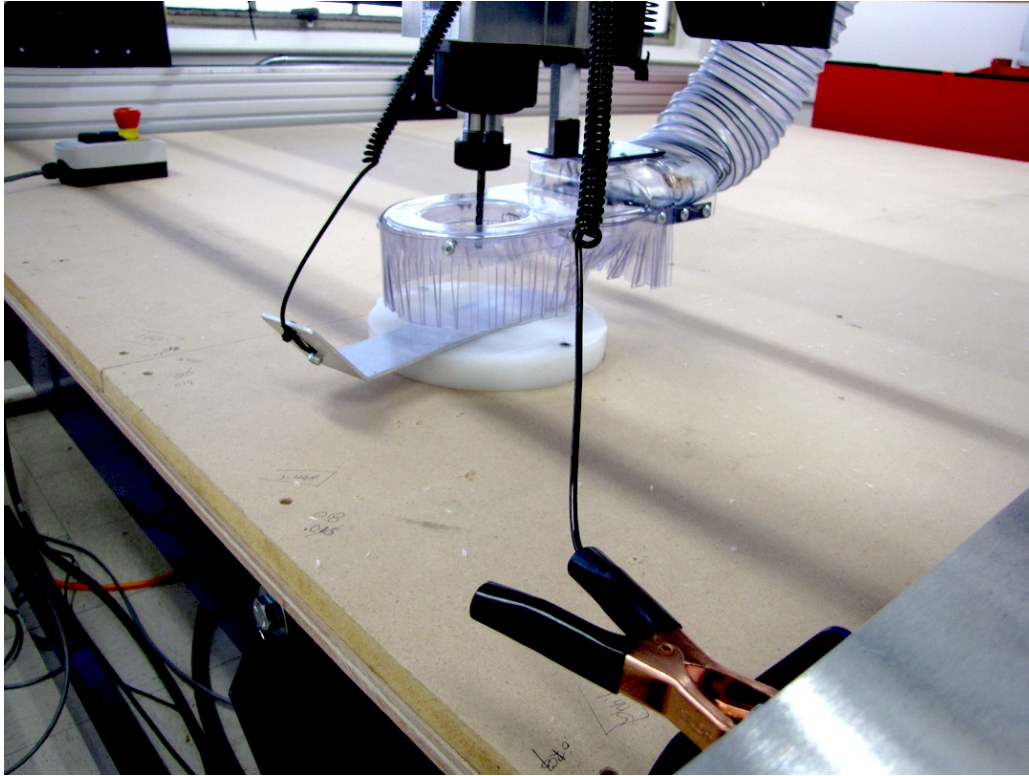
Figure 23: Zero Z Axis with Z Plate

30. Now type **C2** in your interface **COMMAND LINE**, to **ZERO Z AXIS W/ Z PLATE** and wait for the following dialog box (Figure 24).

    Note: Allow the plate and the end mill to gently touch two times, then look at your interface and you will see a green light flash every time these two components come into contact.

Figure 24: Zero Z Axis with Z Plate Dialog Box

31. Click **OK** when you are ready for the **SPINDLE** to go through a 2 step cycle of lowering and raising itself until it touches the aluminum **PLATE** twice.

32. Once this completes, click on 'ok' again to finally accept the changes set the Z axis in the ShopBot 3 software

33. Insert the **KEY** at the end of your **TOOTH HOLDER** into the control box. This activates the spindle (Figure 25).

Figure 25: Key to activate Spindle Switch

34. Set your spindle speed manually in the **SPINDLE CONTROL BOX** by clicking the **UP** and **DOWN** arrows (Figure 26). This can be adjusted real-time even during a ShopBot operation. Spindle Speed is set in 1K or 0.1K increments. Figure 25 indicates a speed of 12K RPM.

Figure 26: Spindle Control Box

35. Turn on the **DUST COLLECTOR**. Have your **SAFETY GLASSES** on. Wear **EAR PROTECTION**.

Figure 27: Dust Collector Switch

36. In ShopBot 3, go to **File> PART LOAD>** and select the ShopBot file you created ending in .SBP. This file is called **NASA_WORM-1inch_thick.SBP.**
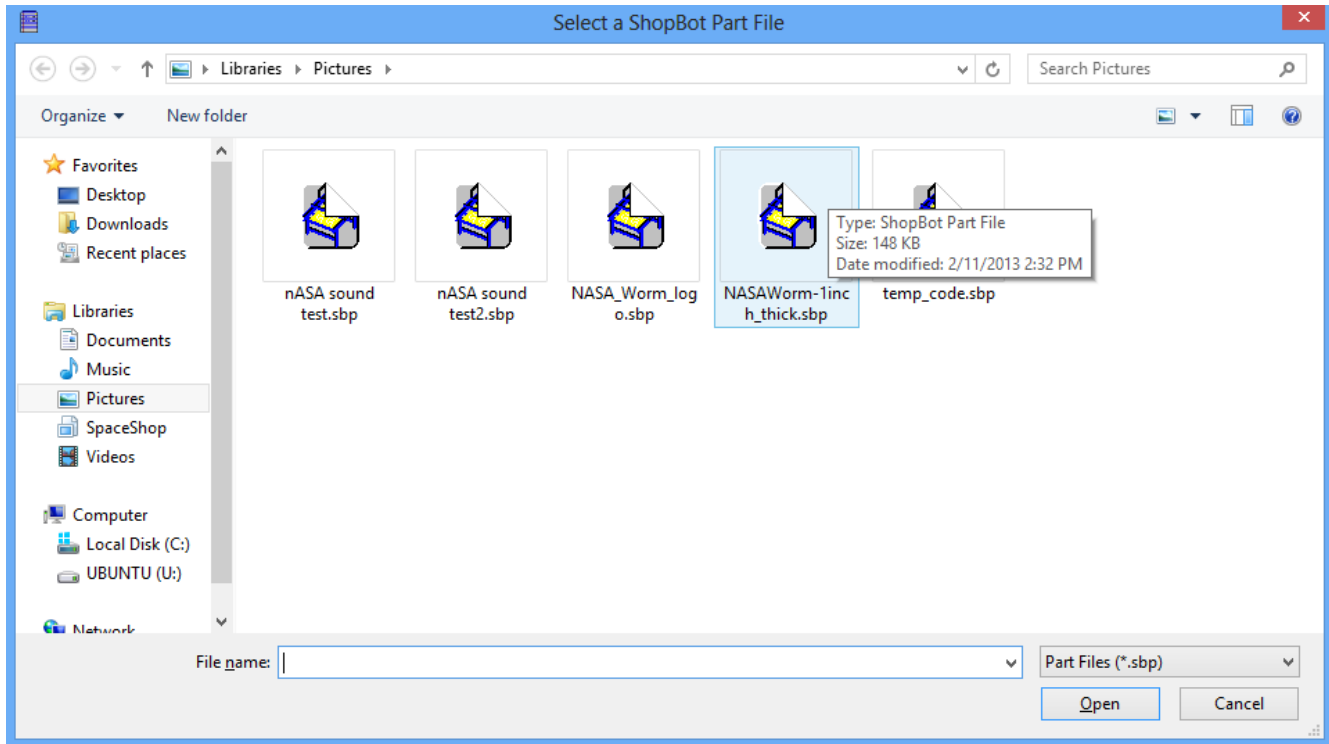

Figure 28: Part File Load

37. After you click on the file, you will see the **START** dialog box. Check to see you loaded the correct file under Part File Name (Figure 29).

38. Click on **START.**

Figure 29: Part File Load Dialog Box

NOTE: If you want to conduct an AIR PASS to see if the traces don't interfere with any screws, then you will need to go back to step 28. All you are changing here is the height of the Z-axis. DO NOT CHANGE YOUR X & Y AXIS. Move the spindle 4-6 inches above your material and click Z2. DONE. Now load your Part File again and DO NOT CLICK ON THE START BUTTON on the dongle. Click OK in figure 26 and the spindle will move and trace the file exactly as you set it, starting at the center of the material but 4-6" above that height. If you don't notice any issues where traces interfere with screws , then proceed with step 39.

39. The dialog box in figure prompts you to do two things. **READ THE NEXT STEPS CAREFULLY BEFORE YOU DO ANYTHING**.
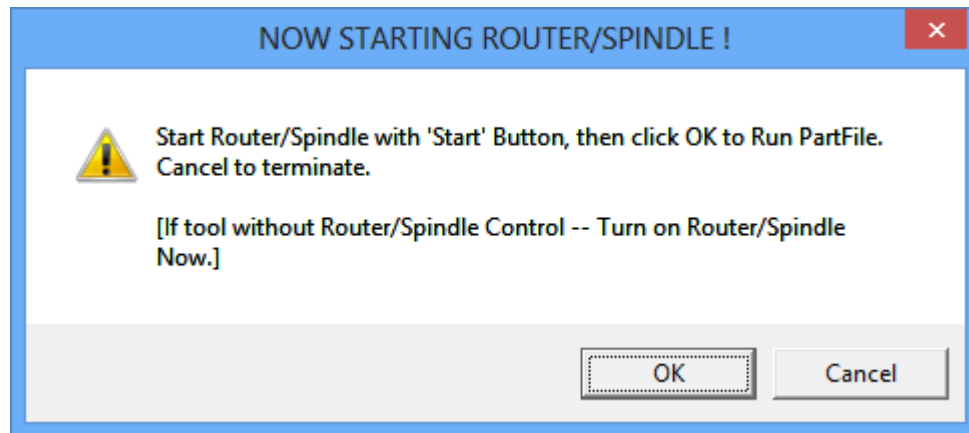
Figure 30: Start Spindle Dialog Box

40. The dialog box in figure 30 asks you to press the **GREEN START** button on the **DONGLE**. If you click on start in figure 31, then your spindle will start spinning. Click **START**.

Figure 31: Start Spindle

41. Click on **OK** in the dialog box, which signals that the Shopbot will officially start operating on the file you loaded.

42. ***PICK UP THE DONGLE AND NEVER SET IT DOWN WHILE YOU ARE OPERATING A JOB ON THE SHOPBOT. IN CASE OF EMERGENCY, HIT THE ESTOP BUTTON (STOPS THE JOB COMPLETELY AND RESETS EVERYTHING) OR CLICK ON THE SPACEBAR ON YOUR KEYBOARD (THIS PAUSES THE JOB AND PRESERVES COORDINATES)***

43. Hit the **SPACE BAR** only if you want pause the operation. This stops the spindle from spinning and moving at the location where you had stopped the operation. You can always continue by clicking on the **RESUME** button in your software interface.

   Note: Additional buttons next to the **RESUME** button include the **INSERT** command. This command allows you to change the **FEED RATE** under **MOVE SPEED**. The number for example may be 5.98, which means the **GANTRY** is moving 5.98 in/sec. You can change this number by typing a new number in the box and clicking **ENTER**. Then click **ESC** and finally **RESUME** to continue your job.
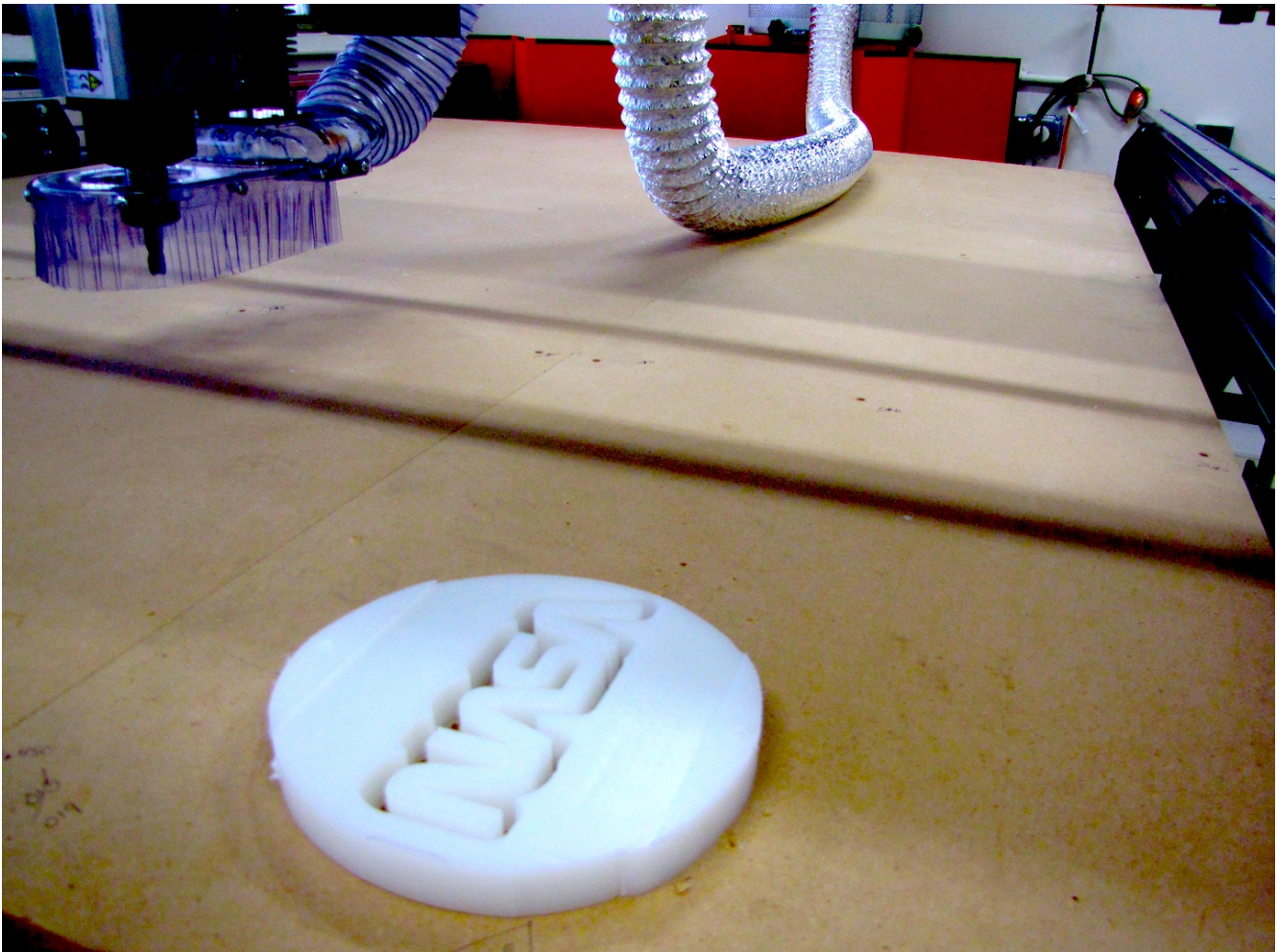

Figure 32: NASA Worm Logo Completed

44. When you have completed your job on the Shopbot, the spindle will return to the starting position of the job and stop. Wait a few minutes until the spindle stops spinning before you continue.

45. Now we need to replace our ½" end mill with a ¼" end mill to do the cut out. To review assembly and disassembly of spindle head, consult steps 16-20.

46. Once you have changed your end mill, consult step 36 to reload your second file called **NASA_WORM_LOGO_CUTTING.SBP**. You will **NOT NEED TO SET XYZ** axes. These are automatically preserved from the previous cut, as long as you have not click on **RESET**.

47. After completing the cutout operation, the spindle will again return to its starting position (center of the material in our case).
48. **TURN OFF** the dust collection system.

49. Type **K** on the software interface and click on the **RIGHT** arrow to move the **GANTRY** away from you along the **X AXIS**. We do this to make space to disassemble our layers from the ShopBot Table.

50. Rotate the key on the **CONTROL BOX** and take it out(Figure 25).

51. Rotate the **RED SWITCH** in figure 2 and turn **OFF** the ShopBot.

52. Terminate the ShopBot software and logout of the computer.

53. Your part should be removed as necessitated by the initial fixture method. Since we screwed our part in, we will use a drill to remove both screws from the **FINAL LAYER**. Then we will remove 4 screws from the **SACRIFICIAL LAYER**.

54. Clean the bed using the vacuum to remove any sawdust or debris that remains on the machine bed.

55. Make sure to remove and put back the **COLLET, COVER NUT**, and **END MILL** in their designated toolboxes.

56. Congratulations! You have succesfully completed the ShopBot Training!

To learn more advanced techniques, such as work holding or end mill selection, please consult a SpaceShop staff member for more information.